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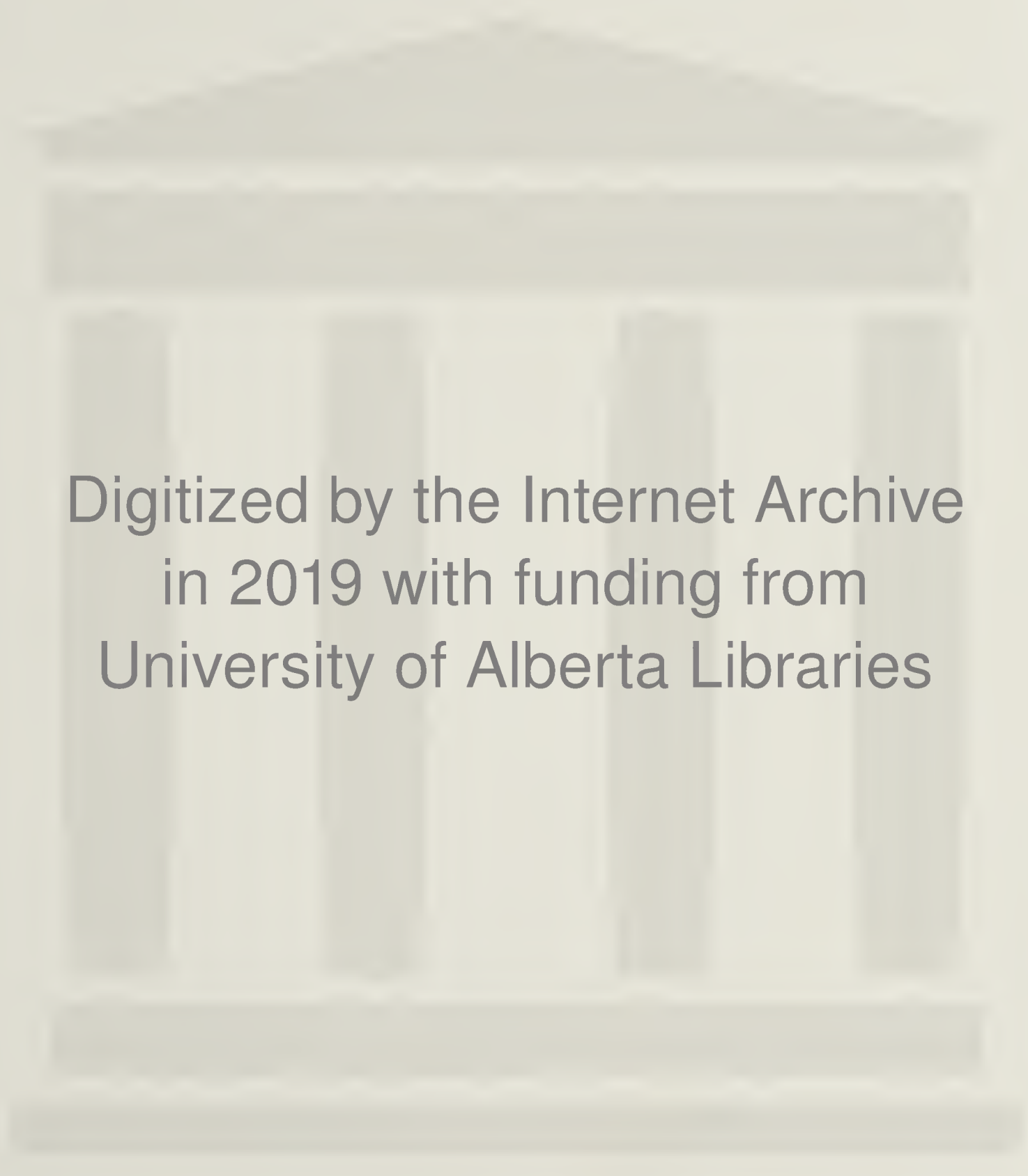
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THE UNIVERSITY OF ALBERTA

APPLICATION OF THE SPECIFICITY  
CONCEPT TO FOUR MEASURES OF  
MUSCULAR ENDURANCE

A THESIS

SUBMITTED TO THE FACULTY OF  
GRADUATE STUDIES IN PARTIAL FULFILLMENT OF THE  
REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

FACULTY OF PHYSICAL EDUCATION

BY

JOHN PETER STOTHART

EDMONTON, ALBERTA

AUGUST, 1965.





APPROVAL SHEET

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Application of the Specificity Concept to Four Measures of Muscular Endurance", submitted by John Peter Stothart in partial fulfillment of the degree of Master of Science.



## ABSTRACT

Relationships among four similar measures of muscular holding endurance of the right quadriceps were analyzed in an endeavor to show the extent to which the performance measures were specific. The measures varied only in angle of hold and/or load used. Load was either thirty or forty-five percent of the maximum isometric strength at the angle tested - either 130 degrees or 160 degrees.

Forty-two male university students with mean age 19.9 years, mean height 69.9 inches, and mean weight 159.4 pounds, were tested over a three-week period with one testing session per week per subject.

Component analysis and intercorrelations of muscular holding endurance measures revealed that although an endurance component was common to all measures, a secondary 'angle' component was sufficient to make the endurance measures specific to the angle tested at. Endurance was not specific to the load used.

Low, negative correlations were evident between isometric strength and holding endurance.



Moderate relationships were found between knee-ankle length and endurance but partial correlations remained relatively unaltered from the original endurance intercorrelations.



## ACKNOWLEDGEMENT

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## CHAPTER I

### STATEMENT OF THE PROBLEM

Introduction. Henry (45) claims that no longer is it possible to justify the concept of unitary abilities such as strength, endurance, coordination and agility, since the evidence shows that these abilities are specific to the task or activity.

Recent research does, in fact, point to the very specific nature of performance, training and learning. This means, virtually, that various performance measures will, themselves, be specific to their own peculiar pattern of execution (3, 20, 36, 37, 39, 40, 41, 44, 45, 61, 65, 66, 72).

Gardner's study (37) in which he trained groups of 15 subjects at each of three different angles of knee extension ( $115^{\circ}$ ,  $135^{\circ}$ ,  $155^{\circ}$ ) using six-second isometric contractions and  $2/3$  maximum load, three times weekly for six weeks, showed that strength gains were observed only at the particular angles trained at. No significant strength gains were evident at any other angles tested. This is striking evidence of the specific nature of strength training. The specific nature of things may ultimately be decided by the specific training undergone by that particular muscle or muscle group in terms of rate of work, position of limbs, body posture, amount of work, size of resistance and pattern of movement.



In a study of grip dynamometer strength Henry and Smith (47) found that individual differences were 54 percent specific to the hand tested (i.e.  $1-r^2 = .54$ ), leaving 46 percent general hand strength ability. Specificity as applied in this case refers only to the specific variability of the two measurements, not necessarily to the 'training' of the parameter.

Actual specificity in muscular endurance has not been studied to the extent that other areas have. In an endurance training study, Kincaid (61) looked at the factor of work rate and subsequently found that each of his three groups had better performances at the lower work rates regardless of whether they had trained at that rate. He concluded that muscular endurance performance is not specific to the rate of training.

Ross (95) found the ability to perform chins to be correlated .27 (significant at .05 level) with the ability to perform the bent arm hang. This illustrated a comparison between the ability of the same muscle group to perform an isotonic task and a static or holding task.

Although the correlation (.27) was significantly greater than a zero order correlation the amount of variability held in common between these two tasks is very low (7%).

Hansen conducted a series of three studies (39, 40, 41) in which he investigated the effects of training on three





types or measures of muscular endurance. The measures were:

1. Repeated isometric contractions.
2. Dynamic contractions.
3. Sustained isometric contraction.

His findings were as follows:

1. Training at repeated isometric contractions greatly increases an individual's ability to perform repeated isometric contractions (1058%).
2. Training at repeated isometric contractions will significantly increase the ability to do repeated dynamic contractions but the increase is not as dramatic as in (1.) (41%).
3. Training at repeated isometric contractions does not appreciably increase isometric or dynamic strength.
4. Training dynamically with heavy resistance, increases dynamic and isometric strength and dynamic endurance but does not affect isometric endurance or sustained isometric holding.
5. Training with part maximum loads at isometric holding, increases dynamic endurance (92.5%) and isometric endurance (84%) as well as the ability to repeat isometric contractions (219%), but does not increase the dynamic endurance or repeated isometric contractions to the extent that the specific training at those tasks did.





Lawther (69) states:

Endurance is to a considerable degree, specific to an activity and, because of this, a person should train in the specific type of endurance called for.

From the foregoing studies and discussion it would appear that there is some relationship between what we might call "kinds" of endurance but that the relationship is probably of relatively low order. If evidence was to be produced indicating a high degree of specificity within or between measures of muscular endurance which are very similar but which differ from each other only in amount of resistance or angle of hold, then this evidence would be strong argument for the idea that instead of the capacity for endurance we may have capacities for endurances.

The Problem. It is the purpose, then, of this study to examine a number of subjects with respect to four similar holding endurance measures, to subsequently determine the relationships among these measures and to finally interpret the degree with which the abilities to perform these tasks are specific to the particular tasks. In addition, strength-endurance relationships, strength intercorrelations, and age, weight, height and leg length relationships with strength and endurance will be ascertained.

Assumption. Motivation as a limiting factor in the performance and expression of the subjects concerned in the present study will be minimized through the application of constant motivating techniques.



Limitations. The compass of this study is limited by the selected measures of muscular endurance, the apparatus used to measure them, the subjects, the author's experimental technique and the statistical procedures used in analysis.

Definition of Terms.

Muscular Endurance. This is the capacity of the muscle or muscle group to persist in an activity with a definite rate, pattern, position and load, and is measured in time.

Maximum Holding Endurance Time (MHET). MHET is the period of time that a given muscle or muscle group has the ability to maintain a given tension at a given joint angle and/or over a given restricted range.

Maximum Isometric Strength (MIMS). MIMS is that maximum tension a muscle or muscle group is capable of exerting in a single concentrated contraction.

Specificity. Specificity is the dependence of a physical event upon its specific or precise pattern, load, rate, repetition and duration.

Vital Statistics. Vital Statistics shall, for the extent of this study refer to age, height, weight and leg lengths.



## CHAPTER II

### REVIEW OF THE LITERATURE

Endurance Versus Strength. Schools of thought which exist today concerning the relationship between muscular endurance and muscular strength are in great conflict. On the one hand are those individuals who feel that there is a relationship between strength and endurance and on the other is the feeling that there is either no relationship or a negative relationship between the two.

Fait (31) states: "since there is a relationship between muscular strength and muscular endurance, muscular strength can be estimated by determining endurance." Kraus and Hirschland (62) consider, as evidenced by inspection of the Kraus-Weber test items, that the term strength is equivalent to holding tasks of ten seconds duration. An extensive factor analysis study has been done by Fleishman, et al (35), in the area of strength and endurance. After analysis of a battery of thirty such tests, the conclusion drawn was that three main 'strength' factors, static strength, explosive strength and dynamic strength were found. Dynamic strength, they related, is the ability to exert muscular force repeatedly or continuously over time: "It represents muscular endurance and emphasizes the resistance of muscles to fatigue," (34). They go on to say, however, that: "no





separate endurance factors appeared," (35:32). All inter-factor correlations were low grade and non-significant.

Start and Graham (104:199), found a highly significant relationship between isometric strength and absolute isometric endurance ( $r = .749$ ,  $N = 30$ ) in addition to a low, non-significant, negative correlation between isometric strength and relative isometric and endurance ( $r = .356$ ).

Tuttle, et al (112, 113) found results very similar to those of Start and Graham (104). In studying the relationships between strength and average strength over one minute (absolute endurance) as well as between strength and average strength over one minute relative to maximum strength (relative endurance), Tuttle, et al found that in all cases of the former relationship (strength versus absolute average strength for one minute) the correlations were high and positive ( $r$ 's =  $.66$  to  $.97$ ,  $N = 23$ ). All correlations between strength and relative average strength for one minute were moderate and negative ( $r$ 's =  $-.26$  to  $-.81$ ).

Jokl (56) subscribes to the school that believes no relationship exists between strength and endurance and bases his argument as follows:

A hypertrophic muscle is well equipped to meet situations of the kind which caused its structural adaptation, that is to say, situations demanding a display of strength. However, a muscle thus adapted is not able, by virtue of this anatomical adjustment, to deal with other tasks which it may encounter in the course of





physical activities. For example, endurance, the ability to work efficiently for an extended period, taxes different properties. Hypertrophy of muscle may even constitute a handicap in the performance of muscular tasks demanding endurance. The opposite statement also holds good, as is borne out by the limited strength of the child's muscles, though children possess as a rule, great powers of endurance. The principal adaptive reaction of tissues to physical performances demanding endurance is increased capillarization, which has been demonstrated in the heart, brain, anterior horns of the spinal cord, and skeletal musculature. It is significant that the last named adjustment occurs regularly in response to physiological usage. (56:170).

.....

The two forms of adaptation of muscle, hypertrophy and capillarization, occur specifically as a result of two distinctly different physiological stimuli. ... frequent display of strength evokes hypertrophy whereas frequent sustained effort increases capillarization. (56:175).

Delorme's view (25) closely parallels that of Jokl by claiming that heavy resistance and low repetitions are indicative of 'power-building' exercises, whereas low resistance and high repetitions are 'endurance-building'.

These are two entirely different types, each one producing its own results and each being wholly incapable of producing the results obtained by the other. (25).

A similar idea is expressed by Brouha (11) who maintains that gain in absolute strength does not always mean a greater endurance. Pierson and Rasch (90) argue further, that training for strength has a negative effect on endurance. Asmussen (2) explains that muscle strength is the maximal tension torque that a muscle group can produce and is dependent upon neuromuscular coordination, skill, and tensile



strength of muscle fibers. Endurance, says Asmussen, is mainly dependent upon the transportation capacity of the cardiorespiratory system and is therefore limited by muscular fatigue.

In his studies on cranking and pedalling ergometry, Ross (96) has reported a number of strength-endurance relationships, among which are included correlation coefficients between cranking strength and cranking endurance ( $r = .348$ ,  $N = 30$ ), and between pedalling strength and pedalling endurance ( $r = .142$ ,  $N = 30$ ). Both coefficients are statistically insignificant. Wedemeyer (116) found correlations of .28 and .18 between sit-up strength and two-minute sit-ups and between sit-up strength and sit-ups to exhaustion, respectively. Both correlations were insignificant ( $N = 47$ ). Smalley and Smalley (102) report similar insignificant correlations between arm-shoulder girdle strength and endurance as measured by squat thrusts ( $r = .140$ ,  $N = 244$ ).

Cumbee and Harris (18) found that a significant negative correlation ( $-.429$ ) existed between an explosive power factor (as determined by the medicine ball throw) and an endurance factor (including chins, dips and bent arm hang).

Endurance Defined. In spite of the great variability of 'expert' opinion in the definition of endurance, there are general trends and consistent lines of thinking.

General Endurance. Webster's Dictionary (115) defines





endurance as "the state or capacity of lasting or continuance." This thought is generally adhered to by most authorities in the field but slight changes in meaning often appear. Most generally defined, as by Consolazio, et al (19), "endurance is prolonged effort;" or by Hansen (39, 40), "endurance is equal to the working capacity." Similarly, Morehouse and Rasch (81) claim that "endurance is the ability to continue work." More elegantly stated by Lawther (69), "endurance is a physiological condition manifested by the length of time one can persist at a particular activity." "Endurance," suggests Karpovich (58), "may be thought of in terms of how long a certain exercise can be continued." Kincaid introduces another aspect when he states that "endurance is the capacity to postpone fatigue" (61).

Muscle Endurance. Howell (49) describes muscular endurance as "the ability of an individual to continue successive repetitions against a fixed amount of resistance." Kincaid's concept of endurance is identical to that of Howell's, but Kincaid goes on to say that muscular endurance is limited by fuel and oxygen supply, waste removal, and exhaustion of motor and neuromuscular mechanisms (61).

Swegan (108) makes more restrictions, indicating that he feels "muscular endurance is the ability to persist at a defined movement, at a defined rate as measured in time."

In a different vein, Larson (67) considers muscular



endurance to be the capacity for long continued contractions.

A like definition is that of Richardson (92), who states:

"muscular endurance or holding time is the ability to maintain a given sub-maximal weight, at a given angle, over time."

Muscular Endurance Measures. Measures of muscular endurance might be more easily discussed if the literature to be cited were dichotomized to include dynamic or isotonic endurance in which a load was moved over a given angle range or distance repeatedly, and holding or isometric endurance in which the resistance or load was held or maintained at a given joint angle. In doing so, it might naturally be assumed that slight variations in each type do occur.

Dynamic endurance measurements generally include activities to exhaustion, or with a time limit; and although each measures a slightly different ability, similar activities can be and are used for both. Activities which have been used include chins, push-ups, sit-ups, dips, leg lifts, supine press and squat thrusts (7, 12, 32, 35, 51, 64, 67, 73, 77, 95, 96, 102). Other investigators have made use of ergometric-type exercises for pedalling and cranking (15, 50, 53, 95, 96, 111). Time limits have been used by some investigators from ten-second dips to two-minute sit-ups (7, 12, 35, 50, 73). Dennison, et al (26) used Roger's Arm Strength Index which included (chins + dips) (weight/10 + height - 60).





Holding type endurance measures most often used, are single isometric holds to exhaustion, and include such activities as leg raiser, prone leg raise, prone trunk holds, bent arm hangs, hold half sit-ups, hold half push-ups, and a number of holds involving held weights or resistance other than body weight (8, 32, 35, 40, 41, 48, 62, 82, 92, 95, 96). A few researchers (86, 112, 113) have used a type of measurement which they call 'average strength held for one minute' and amounts to a maximum hold for one minute. Lawrence, et al (68) used the thirty second maximum hold which could be repeated ten times with fifteen-second intervals. Similarly, Hansen (36) used a sixty percent maximum load and recorded the time that the subject was able to repeatedly hold the weight at a cadence of five seconds hold, two seconds rest.

Specificity. Henry (45) points out that: "it is no longer possible to justify the concept of unitary abilities such as strength, endurance, coordination, and agility, since the evidence shows that these abilities are specific to the task or activity." Morehouse and Rasch (81) confirm this idea by saying that "each athletic event makes specific demands in terms of its pattern, load, rate, repetition and duration."

Morehouse goes on to apply this concept to training (80):



Type of movement, pattern of movement and posture are specific. . . . Repetition of one type of movement does not increase the performance of another type of movement. The pattern of movement must be duplicated to achieve the best training effect.

A classic study was done by Gardner (37) in which the very specific nature of strength training was researched. Gardner trained subjects at three angles of knee extension ( $115^{\circ}$ ,  $135^{\circ}$ ,  $155^{\circ}$ ) and subsequently found that no group made significant strength gains at other than the angle trained at.

Henry and Smith (47) looked at grip dynamometer strength in thirty males and computed the relationship between the grip strengths of right and left hands ( $r = .68$ ,  $N = 30$ ). Individual differences in strength were found to be fifty-four percent specific to the hand tested, with forty-six percent general hand strength ability. They concluded that hand strength involves abilities that are specific to the individual neuromotor pattern of the right and left hands.

According to Lawther's belief (69), "endurance is to a considerable degree specific to an activity and because of this, a person should train in the specific type of endurance called for." Lawrence, et al (68) bear this thought out in a study in which they trained two groups of subjects; the first at the Delorme method of high weights, low repetitions and the other at thirty-second isometric contractions repeated ten times with fifteen-second intervals.





The first group underwent greater strength increases and the second group made corresponding greater staying power increases.

Kincaid (61), on the other hand, trained three groups of subjects at different rates or cadences of work. All three groups improved significantly better at the lowest rate of work and significantly worse at the high rate of work. Kincaid concluded that work efficiency is not specifically trained to rate. Hansen's series of papers, (39, 40, 41) serve well to illustrate the specific results of training. He found that the ability to repeat isometric contractions could be increased through both repeated isometric contractions and sustained isometric contractions but that the former method was almost five times superior to the latter. The ability to perform holding or isometric endurance was increased only through a training program specific to the task. Dynamic endurance was found to be increased by both dynamic and isometric holding programs of training, but again the former was several times superior to the latter.

Ross (95) found only a very low correlation ( $r = .267$ ,  $N = 908$ ) between chins and the bent arm hang task, but it must be noted that one is a dynamic task and the other a holding task. In a second study, Ross (96) found a significant correlation between cranking and pedalling ( $r = .449$ ,  $N = 30$ ); concluding that there is a high degree of specificity involved in endurance measures as applied to various body parts.





Fleishman's results (35) closely parallel those of Ross but the coefficients are slightly higher in most cases. The following table will serve to summarize the relationships found by Fleishman (35) between holding and dynamic variations of activities carried out by the same muscle.

| Dynamic   | Holding            | Correlation (r) |
|-----------|--------------------|-----------------|
| chins     | bent arm hang      | 0.65            |
| push-ups  | hold half push-ups | 0.54            |
| sit-ups   | hold half sit-ups  | 0.35            |
| leg-lifts | leg raiser         | 0.31            |

The following correlation matrix will illustrate existing relationships between holding measures of different body parts reported by Fleishman (35).

|                   | Leg Raiser | Bent Arm Hang | Hold Half Sit-Up | Hold Half Push-Up |
|-------------------|------------|---------------|------------------|-------------------|
| leg raiser        | --         | 0.38          | 0.32             | 0.27              |
| bent arm hang     | 0.38       | --            | 0.40             | 0.57              |
| hold half sit-up  | 0.32       | 0.40          | --               | 0.29              |
| hold half push-up | 0.27       | 0.57          | 0.29             | --                |

These correlations that Fleishman (35) has found are all significant beyond the .01 level of confidence ( $N = 201$ ), and generally indicate that there are undoubtedly, relationships between these various endurance measures, with the higher correlations between measures using arm or shoulder activities; but that these measures are on the whole rather



more specific than general.

It is, therefore, of critical importance to study relationships between similar types of endurance tasks performed with the same muscle, but in different positions, since the literature has given some indication of relationships which exist between dissimilar endurance measures using the same muscles, and between similar endurance measures using different muscles.



## CHAPTER III

### METHODS AND PROCEDURES

Description of Subjects. Forty-two male University of Alberta freshmen were used as subjects. All were year round residents in the city of Edmonton. Their mean age was 19.9 years (standard deviation 2.6 years); their mean height was 5 feet 10 inches (standard deviation 2.4 inches); and their mean weight was 159.4 pounds (standard deviation 18.5 pounds).

#### Thesis Design.

Experiment Length. Testing was carried on throughout the day and evening over a four week period, excluding Sundays. For any one given subject, testing was completed in a three week period with one testing session per week at approximately the same time in the day.

Testing Schedule. The initial testing session included the following measurements:

1. Maximum isometric strength (MIMS) of the right quadriceps muscle at knee extension angles of  $160^{\circ}$  and  $130^{\circ}$ .
2. Total body weight.
3. Total body height.
4. Total leg length from hip to ankle, partial leg lengths from hip to knee and from knee to ankle.





Age in years and months was recorded for each individual as well.

The final two testing sessions were solely concerned with the testing of maximum holding endurance times. There was a total of four endurance tests with two tests given at any one session, randomly ordered so that an equal number of each possible combination of two of the four tests occurred. The four tests were:

1. Maximum holding endurance time (MHET) at knee extension angle of  $160^{\circ}$  and 30 percent of MIMS as load.
2. MHET at a  $160^{\circ}$  knee extension angle and 45 percent of MIMS as load.
3. MHET at a  $130^{\circ}$  knee extension angle and 30 percent of MIMS as load.
4. MHET at a  $130^{\circ}$  knee extension angle and 45 percent of MIMS as load.

#### Equipment.

MIMS Testing Apparatus. All strength testing was carried out on a Medart #339 Massage Table (Figure I) modified for strength testing, and similar in design to the Clarke Testing Table (16:5). The tensiometers used to measure cable tension for the isometric strength measurements were T5 Cable Tensiometers (manufactured by the Pacific Scientific Co., Inc.) and of the type originally used in aircraft testing (16:2). The pulling assembly, including chain,





Figure 1. MIMS TESTING APPARATUS

- A. Modified Medart no. 339 Massage Table
- B. Cable Tensiometer
- C. Pulling Assembly







Figure 2. MHET TESTING APPARATUS

- A. Modified Quadriceps Rehabilitation Table
- B. Measurement Arm
- C. Angle Indicator Unit
- D. Safety Belt
- E. Stop Watch







Figure 2. MHET TESTING APPARATUS

- A. Modified Quadriceps Rehabilitation Table
- B. Measurement Arm
- C. Angle Indicator Unit
- D. Safety Belt
- E. Stop Watch



Measurement of Leg Lengths. In the measurement of the various leg lengths three points were first located and marked with ball-point pen:

1. Greater trochanter of proximal end of femur.
2. Middle of lateral condyle of distal end of femur.
3. Middle of lateral malleolus of distal end of fibula.

The hip to knee measurement was from point one to point two; the knee to ankle measure was from point two to point three and the total measure was the sum of the two. For purposes of placement of the strap for MIMS measurement a mark was made exactly midway between points two and three.

Measurement of Strength. The subject was seated on the testing table (see Figure I) in a backward leaning position, arms extended with elbows locked, and hands grasping the sides of the table. The back of the subject's right knee was comfortably against the edge of the table. The regulation strap was placed around the leg halfway between the knee and ankle joints. The chain of the pulling assembly was attached to a hook on the frame of the table such that the angle of pull was at 90 degrees to the assembly and the knee extension angle at 160 degrees or 130 degrees. The experimenter placed his arm over the subject's thighs and held the far edge of the table, so as to minimize the lifting of the buttocks during the pull. The subject was then





instructed to produce a slow, even pull to begin with and then quickly reach maximum effort. The 'shout' technique was used to motivate the subject and draw his attention to the task. Two trials were made at each angle, trials being separated by approximately two to three minute intervals (16:29).

Measurement of Holding Endurance. The load to be used, either thirty or forty-five percent of the subject's MIMS at either  $160^{\circ}$  or  $130^{\circ}$  of knee extension was first placed on the resistance side of the measurement arm (note: the amount of resistance had to be adjusted to the angle of the particular hold - either  $160^{\circ}$  or  $130^{\circ}$  - by dividing the given thirty or forty-five percent load by the cosine of the angle). The measurement arm was then set at the desired testing angle. The subject seated himself on the modified quadriceps rehabilitation table and assumed the same position as was used for strength testing. A wide belt was secured firmly over the thighs to stabilize the buttocks. Instructions were then given regarding the nature of the task. The subject was told that he was to take the weight strain and maintain the knee angle for as long as possible. The angle indicator, he was told, would show a green light if and when the angle of the hold was depressed 2.5 degrees, followed by a red light when the angle depressed 5 degrees. The subject's object as he was instructed, was to "hold" the green light off, and failing this, to "hold" the





red light off. The angle indicator unit was adjusted prior to loading to insure proper function for each test. As the subject took the strain of the weight, the stop watch was started. The watch was stopped when the subject failed to keep the red light off. A ten minute rest was then given, and the first trial of the second test for that session was performed. Second trials for each test followed at ten minute intervals.

The choice of angles, loads and rest period was not arbitrarily determined. Prior to the establishment of this design a pilot study was carried out in which the various parameters of load and rest period were studied. It was observed that the measures which would prove most feasible for testing were loads of 42 percent and 29 percent with a ten minute rest between trials. Other possibilities tested included a 15 percent load and combinations of all loads with 5 and 20 minute rests between trials. The angles of knee extension for hold were chosen on the basis of two contributing factors. The first was that since the resistance side of the measurement arm was at the same angle as that of the leg, a factor equal to the cosine of the angle had to be divided into the actual percentage load to get the amount of weight to be placed on the resistance bar. Since the cosine of the angle decreases as the angle decreases, any angle below  $130^{\circ}$  made it impossible to place the



## CHAPTER IV

### RESULTS AND DISCUSSION

Introduction. Due to the fact that results reported will be concerned, for the most part, with correlational type data, it will be useful to look at a few basic considerations regarding the interpretation of correlation coefficients.

Ferguson (33:108) explains that:

In attempting to conceptualize the degree of relationship represented by a correlation coefficient it is more meaningful to think in terms of the square of the correlation coefficient instead of the correlation coefficient itself.

The square of the correlation coefficient (represented by  $r^2$ ) is a ratio of the variance of one variable that can be predicted from, or explained by the variance of a second variable, to the total variance of the first variable (33). It is most often expressed as a percentage and is interpreted as the proportion of total variance which is held in common by or is general to both variables. The variance remaining or yet unaccounted for is then equal to  $1-r^2$  and is often discussed as the  $k^2$  factor. This factor is a composite of error variability and variability due to components specific or unique to the two variables concerned. The  $k^2$  factor is generally referred to as the specificity factor, however,



the portion of this factor which is due to the unique variance of two variables is somewhat determined by the reliability of the two variables. When reliability is high, the amount of variability due to error is low and  $k^2$  is virtually the specificity factor alone.

Means, Standard Deviations and Ranges of Vital Statistics.

The means, standard deviations and ranges for age, height, weight and leg lengths may be found in Table I.

TABLE I

MEANS, STANDARD DEVIATIONS AND RANGES OF AGE, HEIGHT,  
WEIGHT AND LEG LENGTHS (N=42)

|                      | Mean  | Standard<br>Deviation | Range       |
|----------------------|-------|-----------------------|-------------|
| Age (years)          | 19.9  | 2.6                   | 18.1 - 28.2 |
| Height (inches)      | 69.9  | 2.4                   | 65.5 - 74.5 |
| Weight (pounds)      | 159.4 | 18.5                  | 118 - 200   |
| Leg Lengths (inches) |       |                       |             |
| Hip-Knee             | 16.4  | 0.8                   | 14.8 - 18.0 |
| Knee-Ankle           | 16.9  | 0.9                   | 15.0 - 18.8 |
| Total Leg            | 33.4  | 1.5                   | 30.3 - 36.5 |

Intercorrelations Among Vital Statistics. The correlation coefficients for certain vital statistics measured are shown in Table II. Fleishman (35) has published age, height and weight correlations which are similar to those observed in Table II. For instance, the age - weight and age - height correlations are both nonsignificant and of very low order in both studies ( $r = -.10$  and  $-.07$ ,  $N = 42$ , respectively, in the present study and  $.21$  and  $.07$ ,  $N = 201$ , respectively in







TABLE II

CORRELATIONS AMONG AGE, HEIGHT, WEIGHT  
AND LEG LENGTHS (N = 42)<sup>c</sup>

|            | Height | Weight            | Hip-Knee                      | Knee-Ankle        | Total Leg         |
|------------|--------|-------------------|-------------------------------|-------------------|-------------------|
| Age        | -.07   | -.10 <sub>b</sub> | -.23 <sub>b</sub>             | -.17 <sub>b</sub> | -.22 <sub>b</sub> |
| Height     |        | .57 <sub>b</sub>  | .70 <sub>b</sub> <sup>a</sup> | .88 <sub>b</sub>  | .86 <sub>b</sub>  |
| Weight     |        |                   | .34 <sup>a</sup>              | .44 <sub>b</sub>  | .43 <sub>b</sub>  |
| Hip-Knee   |        |                   |                               | .69 <sup>b</sup>  | .91 <sub>b</sub>  |
| Knee-Ankle |        |                   |                               |                   | .93 <sub>b</sub>  |

<sup>a</sup> Significantly different from zero at .05 level of confidence (critical  $r = \pm .304$ ).

<sup>b</sup> Significantly different from zero at .01 level of confidence (critical  $r = \pm .393$ ).

<sup>c</sup> Degrees of freedom =  $N - 2 = 40$ .

Fleishman's study), and the height-weight coefficient reported by Fleishman is identical to that found in the present study ( $r = .57$ ,  $N = 201$ ).

Leg length intercorrelations are highly significant (.01 level) (i.e. greater than zero) as might be expected ( $r = .69$ ,  $.91$  and  $.93$  for hip-knee and knee-ankle, hip-knee and total and knee-ankle and total, respectively).

Age, Height, Weight and Leg Length Correlations With MIMS and MHET Measures. Table III shows the correlations obtained between certain vital statistics and the strength (MIMS) and endurance (MHET) measures. The one significantly negative coefficient between age and strength measured at  $160^{\circ}$  ( $r = -.33$ ) is not consistent with Fleishman's results



TABLE III

AGE, HEIGHT, WEIGHT AND LEG LENGTH CORRELATIONS  
WITH MIMS AND MHET MEASURES (N = 42)<sup>c</sup>

|                    | Age               | Height           | Weight           | Hip-<br>Knee | Knee-<br>Ankle   | Total Leg        |
|--------------------|-------------------|------------------|------------------|--------------|------------------|------------------|
| MIMS<br>(160°)     | -.33 <sup>a</sup> | .27              | .57 <sup>b</sup> | .29          | .22              | .27              |
| MIMS<br>(130°)     | -.26              | .05              | .50 <sup>b</sup> | .13          | .07              | .11              |
| MHET<br>(160°-30%) | .03               | .50 <sup>b</sup> | .21              | .25          | .46 <sup>b</sup> | .40 <sup>b</sup> |
| MHET<br>(160°-45%) | -.10              | .45 <sup>b</sup> | .32 <sup>a</sup> | .26          | .47 <sup>b</sup> | .40 <sup>b</sup> |
| MHET<br>(130°-30%) | -.11              | .34 <sup>a</sup> | .18              | .07          | .40 <sup>b</sup> | .27              |
| MHET<br>(130°-45%) | .01               | .39 <sup>a</sup> | .27              | .14          | .47 <sup>b</sup> | .34 <sup>a</sup> |

<sup>a</sup> Significantly different from zero at .05 level of confidence (critical  $r = \pm .304$ ).

<sup>b</sup> Significantly different from zero at .01 level of confidence (critical  $r = \pm .393$ ).

<sup>c</sup> Degrees of Freedom =  $N - 2 = 40$ .

(35:22), but the subjects tested by Fleishman had a lower mean age (18 years, 3 months) coupled with a much lower age standard deviation (1 year, 3 months). The weight - MIMS correlations ( $r = .57$  and  $.50$ ) at 160° and 130° respectively, are similar to those found by Fleishman who reported a weight - grip strength correlation of .49 (N = 201) (35:22). The height and knee-ankle length (or lower leg length) correlations with the endurance measures, although not high, are nevertheless statistically different from zero. It may be



that the longer legged subjects had some mechanical or structural advantage due to the design of the MHET tests. The similarity between the height - MHET correlations and the lower leg length - MHET correlations may simply be construed to be a result of the high lower leg - height correlation ( $r = .88$ ).

Means and Standard Deviations of MIMS and MHET Measures.

The means and standard deviations of the strength and endurance measures are indicated in Table IV. It should be

TABLE IV

MEANS AND STANDARD DEVIATIONS OF MIMS  
AND MHET MEASURES (N = 42)

|                       | Mean  | Standard<br>Deviation |
|-----------------------|-------|-----------------------|
| MIMS (pounds tension) |       |                       |
| 160°                  | 95.5  | 18.8                  |
| 130°                  | 237.0 | 37.1                  |
| MHET (160°)           |       |                       |
| (time in seconds)     |       |                       |
| 30% (load)            | 209.5 | 61.7                  |
| 45% (load)            | 127.9 | 36.8                  |
| MHET (130°)           |       |                       |
| (time in seconds)     |       |                       |
| 30% (load)            | 101.8 | 28.2                  |
| 45% (load)            | 67.4  | 16.7                  |

noted that the considerable difference in means of MIMS at 160 degrees and MIMS at 130 degrees is greater than was observed by Clarke and Bailey (18) who reported that MIMS at 130 degrees was approximately 40 percent greater than





MIMS at 160 degrees. This compares with a 150 percent difference found in the present study.

The higher endurance scores at the 160 degree angle may be due to the fact that in daily living we use the knee extension angle of 160 degrees far more than we do the angle of 130 degrees, especially at an activity which might be considered of a low resistance, high repetition type (i.e. walking). Also notable is the relationship between the size of each of the MHET measures at 160 degrees (209.5 seconds for 30% load and 127.9 seconds for 45% load) and the size of the corresponding measures at 130 degrees (101.8 seconds for 30% load and 67.4 seconds for 45% load) - the former are both approximately twice as great as the latter.

MIMS and MHET Performance Reliability. Reliabilities for both half test (one trial) and full-test length (two trials) are presented in Table V. The MIMS reliabilities are in accordance with the literature, generally, which shows reliabilities of various strength measures from .86 to .99 (63, 91, 92, 101, 119). Reliabilities of the muscular endurance performances are likewise in accordance with those found by other investigators who report reliabilities of from .71 to .88 (59, 35, 92). It is difficult, however, to draw close comparisons, due to the fact that the numbers of subjects, trials, and methods of



TABLE V

RELIABILITIES OF MIMS AND MHET PERFORMANCES (N = 42)

|        |      | Split-half Reliability<br>(Single Trial) | Full-test Reliability<br>(Two Trials) |
|--------|------|------------------------------------------|---------------------------------------|
| MIMS   | 160° | .91                                      | .95                                   |
|        | 130° | .90                                      | .95                                   |
| MHET   | 30%  | .72                                      | .84                                   |
| (160°) | 45%  | .80                                      | .89                                   |
| MHET   | 30%  | .88                                      | .94                                   |
| (130°) | 45%  | .80                                      | .89                                   |

determining the reliabilities reported by other researchers are unclear or not fully reported.

A further consideration lies in the fact that the reliabilities in Table V are based upon two trials obtained within a very short space of time (five to twenty-five minutes). This factor may have led to slightly higher coefficients due to a spurious correlation which often results when scores are measured under relatively short time intervals. The time interval, for example, does not allow for day to day fluctuation, hence reliability coefficients become inflated (76:151).

MIMS Intercorrelations. The correlation coefficient between strength measures at different angles of knee extension is shown in Table VI to be .81. Another study which reported similar types of relationships (i.e. between strength measures of the same body part but at different



TABLE VI

MIMS AND MHET INTERCORRELATIONS (N = 42)<sup>c</sup>

|                 | MIMS<br>130°     | MHET<br>160°-30%  | MHET<br>160°-45%  | MHET<br>130°-30%  | MHET<br>130°-45%  |
|-----------------|------------------|-------------------|-------------------|-------------------|-------------------|
| MIMS (160°)     | .81 <sup>b</sup> | -.37 <sup>a</sup> | -.20              | -.10              | -.09              |
| MIMS (130°)     |                  | -.29              | -.13 <sub>b</sub> | -.28 <sub>b</sub> | -.11 <sub>b</sub> |
| MHET (160°-30%) |                  |                   | .79 <sup>b</sup>  | .51 <sub>b</sub>  | .53 <sub>b</sub>  |
| MHET (160°-45%) |                  |                   |                   | .63 <sub>b</sub>  | .66 <sub>b</sub>  |
| MHET (130°-30%) |                  |                   |                   |                   | .77 <sup>b</sup>  |

<sup>a</sup> Significantly different from zero at .05 level of confidence (critical  $r = \pm .340$ ).

<sup>b</sup> Significantly different from zero at .01 level of confidence (critical  $r = \pm .393$ ).

<sup>c</sup> Degrees of freedom =  $N - 2 = 40$ .

angles of pull) was done by Shaw (101) who reported correlations of .77 and .82 ( $N = 50$ ) between measures of strength with an angle separation of 45 degrees, and a correlation of .61 with an angle separation of 90 degrees between pulls. Shaw's conclusion (101:42) that as the testing stations approach each other with respect to angular position on the movement arc, the correlations increased, is subject to question since there are but two different angle separations and the fact that one is lower or higher than another does not mean that a trend one way or another is evident. It may, however, be a reasonable hypothesis upon which to base further research.







TABLE VII

GENERAL AND SPECIFIC FACTORS DERIVED FROM  
MIMS AND MHET INTERCORRELATIONS<sup>c</sup>

|                       |                  | MIMS             |                  | MHET 160 <sup>o</sup> |     | MHET 130 <sup>o</sup> |     |
|-----------------------|------------------|------------------|------------------|-----------------------|-----|-----------------------|-----|
|                       |                  | 160 <sup>o</sup> | 130 <sup>o</sup> | 30%                   | 45% | 30%                   | 45% |
| MIMS                  | 160 <sup>o</sup> |                  | 66 <sup>a</sup>  | 14                    | 4   | 1                     | 8   |
|                       | 130 <sup>o</sup> | 34 <sup>b</sup>  |                  | 8                     | 2   | 8                     | 1   |
| MHET 160 <sup>o</sup> | 30%              | 86               | 92               |                       | 62  | 26                    | 28  |
|                       | 45%              | 96               | 98               | 38                    |     | 40                    | 44  |
| MHET 130 <sup>o</sup> | 30%              | 99               | 92               | 74                    | 60  |                       | 59  |
|                       | 45%              | 92               | 99               | 72                    | 56  | 41                    |     |

<sup>a</sup> Above diagonal: general factor coefficients ( $r^2$ ).

<sup>b</sup> Below diagonal: specific factor coefficients ( $k^2$ ) or ( $1 - r^2$ ).

<sup>c</sup> All values expressed as percentages.

MIMS - MHET Correlations. As demonstrated in Table VI, all strength-endurance relationships are low and negative, with only one coefficient ( $r = -.37$ ) significantly different from zero. Table VII, which shows  $r^2$  and  $k^2$  values for all MIMS - MHET correlations and intercorrelations demonstrates the specific nature of strength and holding endurance variability when intercorrelated. For example the  $k^2$  factors range from 86 percent (between MHET-160<sup>o</sup>-30% and MIMS-160<sup>o</sup>) to 99 percent (between MHET-130<sup>o</sup>-45% and MIMS-130<sup>o</sup>) of the variance unaccounted for. Comparable results have been reported by Start and Graham (104) and Tuttle, et al (112, 113). Start and Graham found, when correlating MIMS with relative isometric endurance, a non-significant relationship



of  $-.356$  ( $N = 30$ , critical  $r = \pm .361$ ). Two studies by Tuttle, et al yielded six correlations between various isometric strength measures and corresponding relative holding endurance measures, ranging from  $-.26$  to  $-.81$ . All were significant ( $p = .05$ ) with the exception of the lowest coefficient (critical  $r = \pm .413$ ,  $N = 23$ ). Both studies reported at the same time, relatively high correlations between MIMS and 'absolute' holding endurance measures (with  $r$ 's ranging from  $.66$  to  $.97$ ). These results (104, 112, 113) combined with those in the present study may be interpreted to mean that although a strong man, when compared to a weak man has more absolute endurance, the weak man is generally superior to the strong man in holding endurance tasks with loads relative to strength measured beforehand. An explanation for the negative correlations between strength and relative holding endurance has been proffered by Start and Graham (104) who claim that in strong muscles the katabolic activity would be higher, irritant production greater, and the tissue subject to greater strain (fatigue conditions) than in weaker muscles, due to a higher work load. This suggestion, however, assumes that both stronger and weaker muscles are the same size, which according to Asmussen (2) is erroneous, because it has been shown through muscle strength measurements that it depends on the physiologic transverse area of the muscle concerned. If this is the case, then





although a greater absolute katabolic activity might take place, the relative effects upon the muscle would be the same due to equal strain per unit of muscle size. Still, research is unclear as to the precise linear aspects of the relationship between strength and muscle size, and the Start and Graham idea may have merit after all.

MHET Intercorrelations. MHET intercorrelations may be observed in Table VI, and the derived general ( $r^2$ ) and specific ( $k^2$ ) factors corresponding to them are found in Table VII. The two correlations between endurance measures taken at the same angles but with different relative loads, are virtually the same ( $r = .79$  and  $.77$ ). The  $r^2$  and  $k^2$  factors for both these relationships serve to indicate that the endurance variables concerned have a moderately higher proportion of variance in common with each other than variance not in common with each other.

The inter-angle relationships between both percentage loads of one angle with those of the other, present quite a different picture to the one just discussed. The correlations between the 30 percent load at 160 degrees and the two different loads at 130 degrees are of the same moderate order ( $r = .51$  and  $.53$ ) and the variables concerned are highly unique ( $k^2 = 74\%$  and  $72\%$ , respectively). The final two MHET intercorrelations resemble each other in magnitude as well ( $r = .63$  and  $.66$ ), both being of moderately specific inclination ( $k^2 = 60\%$  and  $56\%$ ). The general trend appears to be such that





the different measures within each angle are general to the angle, but that when measures of holding at one angle are compared to measures of holding at the other angle, the variance held in common is exceeded by the variance specific to the variables. The literature is particularly sparse concerning relationships between endurance measures of the same type taken on the same limb or using the same joint action but varying the angle. Some studies have examined relationships between different types of endurance measures on the same limb or muscle (35, 39, 40, 41, 95, 96) and others have even studied the same type of endurance measure on different body parts (34, 35, 36). Correlations of the former class which have been reported, run from very low to moderate ( $r = .27$  to  $.65$ ) but in no instance was the squared correlation coefficient greater than  $.42$ ; meaning that these types of endurance measures are very specific in terms of variability. Fleishman (35) has reported correlations of the latter class and found coefficients running from  $.27$  to  $.40$  ( $N = 201$ ). In only one case were the body parts the same, and the correlation was found between the bent arm hang and the hold half push-up to be  $.57$ . This final correlation is probably the most similar to the relationships studied in the present problem, both in terms of body part and endurance type as well as in magnitude.



Partial Correlations. Partial correlations which were computed for the MHET intercorrelations, keeping knee-ankle length constant, may be seen in Table VII. Knee-ankle length,

TABLE VIII

CORRELATION MATRIX OF MHET INTERCORRELATIONS  
AND CORRESPONDING PARTIAL CORRELATIONS  
WITH KNEE-ANKLE LENGTH HELD  
CONSTANT (N = 42)<sup>c</sup>

|           |     | MHET 160°        |                  | MHET 130° |     |
|-----------|-----|------------------|------------------|-----------|-----|
|           |     | 30%              | 45%              | 30%       | 45% |
| MHET 160° | 30% |                  |                  | .51       | .53 |
|           | 45% | .73 <sup>b</sup> | .79 <sup>a</sup> | .63       | .66 |
| MHET 130° | 30% | .40              | .54              |           | .77 |
|           | 45% | .40              | .56              | .72       |     |

<sup>a</sup> Above diagonal: MHET intercorrelations.

<sup>b</sup> Below diagonal: MHET partial correlations.

<sup>c</sup> All partial correlations and intercorrelations are significantly different from zero (.01 level of confidence, critical  $r = \pm .393$ , degrees of freedom = 40).

total leg length and height were the only consistently significant correlations with the MHET measures (refer to Table III). The latter two, total leg length and height presumably are moderately correlated with MHET through their association with knee-ankle length and consequently were not used in partial correlations. Due to the size of the knee-ankle length correlations with MHET, it was felt that the intercorrelations among MHET measures should be examined with the knee-ankle length partialled out. The resulting coefficients are not greatly altered from the



originals and examination of Table IX will confirm that

TABLE IX  
GENERAL AND SPECIFIC FACTORS DERIVED FROM  
MHET PARTIAL CORRELATIONS<sup>c</sup>

|                       |     | MHET 160 <sup>o</sup> |                 | MHET 130 <sup>o</sup> |     |
|-----------------------|-----|-----------------------|-----------------|-----------------------|-----|
|                       |     | 30%                   | 45%             | 30%                   | 45% |
| MHET 160 <sup>o</sup> | 30% |                       | 53 <sup>a</sup> | 16                    | 16  |
|                       | 45% | 47 <sup>b</sup>       |                 | 29                    | 31  |
| MHET 130 <sup>o</sup> | 30% | 84                    | 71              |                       | 52  |
|                       | 45% | 84                    | 69              | 48                    |     |

<sup>a</sup> Above diagonal: general factor coefficients ( $r^2$ ).

<sup>b</sup> Below diagonal: specific factor coefficients ( $k^2$ ) or ( $1 - r^2$ ).

<sup>c</sup> All values expressed as percentages.

although there is some indication of an increased variable specificity, the overall pattern of general to specific variance portions is unchanged.

Component Analysis. The foregoing results were concerned with individual relationships between each MHET measure with each other MHET measure. The data were then subjected to component analysis so that all MHET measures could be treated together. Component analysis is designed to provide a 'weighting system' of all variables taken simultaneously, which will determine one or more composite variables (or components) which will best describe the original measures. The extent to which the  $n$  variable space can be reduced to a







TABLE X  
CORRELATION MATRIX FOR COMPONENT ANALYSIS OF ALL MHET  
TEST TRIALS ONE AND TWO

| Variable | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     |
|----------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1        | 1.000 | 0.718 | 0.778 | 0.693 | 0.534 | 0.404 | 0.585 | 0.427 |
| 2        | 0.718 | 1.000 | 0.619 | 0.660 | 0.430 | 0.410 | 0.434 | 0.362 |
| 3        | 0.778 | 0.619 | 1.000 | 0.804 | 0.583 | 0.561 | 0.605 | 0.636 |
| 4        | 0.693 | 0.660 | 0.804 | 1.000 | 0.621 | 0.567 | 0.565 | 0.569 |
| 5        | 0.534 | 0.430 | 0.583 | 0.621 | 1.000 | 0.880 | 0.678 | 0.705 |
| 6        | 0.404 | 0.410 | 0.561 | 0.567 | 0.880 | 1.000 | 0.721 | 0.757 |
| 7        | 0.585 | 0.434 | 0.605 | 0.565 | 0.678 | 0.721 | 1.000 | 0.795 |
| 8        | 0.427 | 0.362 | 0.636 | 0.569 | 0.705 | 0.757 | 0.795 | 1.000 |

| Variable | 1         | 2         | 3         | 4         | 5         | 6         | 7         | 8         |
|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|          | MHET 160° | MHET 160° | MHET 160° | MHET 160° | MHET 130° | MHET 130° | MHET 130° | MHET 130° |
|          | - 30%     | - 30%     | - 45%     | - 45%     | - 30%     | - 30%     | - 45%     | - 45%     |
|          | - Trial 1 | - Trial 2 | - Trial 1 | - Trial 2 | - Trial 1 | - Trial 2 | - Trial 1 | - Trial 2 |



k component space depends upon the number of orthogonal components selected. Assuming that the k components derived from n variables are greatly reduced in number, a more parsimonious explanation of the original data will have thus been achieved. The orthogonal components are obtained and selected on a basis of the total variance they account for, but their importance stems also on whether or not they can be interpreted with physical meaning.

TABLE XI  
MEANS AND STANDARD DEVIATIONS OF ALL MHET  
TEST TRIALS ONE AND TWO<sup>a</sup>

| Variable | Mean  | Standard<br>Deviation |
|----------|-------|-----------------------|
| 1        | 233.4 | 73.5                  |
| 2        | 185.4 | 58.0                  |
| 3        | 144.0 | 44.3                  |
| 4        | 111.7 | 32.2                  |
| 5        | 113.4 | 34.1                  |
| 6        | 90.2  | 23.5                  |
| 7        | 71.4  | 19.5                  |
| 8        | 63.5  | 15.3                  |

<sup>a</sup>See Table X for variables.

Tables X to XIII are presented to indicate the results of the component analysis. Upon closer scrutiny of Table XII, components one and two seem to show definite patterns. Component one is consistently loaded highly for each variable with no variation of direction (i.e. sign). Table XIII shows



TABLE XII

## UNROTATED FACTOR MATRIX OF COMPONENT ANALYSIS

| Variable                | Communalities | Components         |       |       |       |
|-------------------------|---------------|--------------------|-------|-------|-------|
|                         |               | 1                  | 2     | 3     | 4     |
| 1                       | 0.87          | -0.79 <sup>a</sup> | -0.47 | -0.11 | 0.14  |
| 2                       | 0.92          | -0.70              | -0.52 | 0.26  | 0.30  |
| 3                       | 0.92          | -0.86              | -0.27 | -0.20 | -0.27 |
| 4                       | 0.90          | -0.84              | -0.27 | 0.05  | -0.34 |
| 5                       | 0.92          | -0.84              | 0.33  | 0.32  | -0.04 |
| 6                       | 0.95          | -0.82              | 0.45  | 0.27  | 0.00  |
| 7                       | 0.94          | -0.83              | 0.27  | -0.30 | 0.29  |
| 8                       | 0.89          | -0.81              | 0.40  | -0.26 | -0.02 |
| Eigenvalue <sup>b</sup> | 7.30          | 5.29               | 1.18  | 0.45  | 0.38  |

<sup>a</sup> Each component loading is a correlation of the corresponding variable with the optimally weighted sum of all measures.

<sup>b</sup> Eigenvalue-sum of squared component loadings for each component.

TABLE XIII

## EIGENVALUES AND PERCENTAGES OF VARIANCE ACCOUNTED FOR

| Components | Eigenvalue | Variance (%)<br>Accounted For <sup>a</sup> |
|------------|------------|--------------------------------------------|
| 1          | 5.29       | 66.2                                       |
| 2          | 1.18       | 14.7                                       |
| 3          | 0.45       | 5.6                                        |
| 4          | 0.38       | 4.8                                        |
| 5          | 0.30       | 3.8                                        |
| 6          | 0.20       | 2.5                                        |
| 7          | 0.14       | 1.7                                        |
| 8          | 0.07       | 0.8                                        |

<sup>a</sup> Found by dividing corresponding eigenvalue by total variance (i.e. 8.0).





that this component accounts for 66.2 percent of all the variance between variables. Component one is then interpreted as the muscular holding endurance component.

Component two, although only accounting for 14.7 percent of all the variance does account for three times as much variance as any other component, and the moderate loadings have a definite direction trend. The first four loadings, which correspond to all the MHET measures at 160 degrees, are negatively loaded, and the last four loadings, which correspond to all the MHET measures at 130 degrees, are positively loaded. The second component is consequently interpreted as the angle component. The final six components (only two shown in Table XII) are of little consequence, both because of low loadings and inconsistent patterning. As a result, the variance accounted for by these last six components may be considered as "error variance;" and the variance accounted for by components one and two as the "true variance." If reliability is defined as the ratio of true variance to total variance then the variance accounted for by components one and two, divided by the total variance is a reliability measure of internal consistency of the eight variables concerned. This value is calculated to be 80.9 percent, making the comparable  $k^2$  factor 19.1%, i.e. uniqueness among the eight variables. It appears from the foregoing that in general there is one important component which has been labelled muscular holding endurance, which



best defines the eight tests of MHET. There is, in addition, strong evidence to support a second, though less vital 'angle' component.

General Discussion. There is a strong trend in research in the area of physical education toward the concept that when working with human motor and physical development, motor learning and physical measurement we are dealing with a very large number of specific qualities and abilities (45, 69, 80). The degree to which the concept of specificity may be applied is virtually limitless. In the narrower field of endurance, specificity may be studied in several directions as well as in variable degree. For instance, endurance training may be studied on the basis of different types of training regimes (39, 40, 41). Or similar training methods may be studied with an eye on how different body parts and muscles are affected. On the other hand, the measurement of endurance may be researched to decide how different body parts react to similar measurements (35, 96), or how the same body parts react to different types of endurance measurements (35, 95).

It has been shown that different types of training regimes produce very specific effects on the same muscle (39, 40, 41). These results may be due in great part to two things. First it may be that one type of exercise (e.g. isometric) has a lower energy requirement than another (e.g. dynamic), as was found by Clarke (14). Secondly, the difference possibly exists due to a difference in blood





supply which was found to exist by Clarke (14), and Barcroft and Millen (6). Also shown, has been the fact that different muscles react differentially to similar endurance measurements (35, 96). There are a vast number of possible reasons for this effect: muscles have variable optimum work rates and work capacities (97); optimum strength angles of operation vary from muscle to muscle (18); muscles have varying maximum strengths (18); and muscles have different optimum work loads (71).

In the present study, similar endurance measures were applied to the quadriceps muscle in order to see if specificity of performance could be detected. Specificity was shown to be evident between measures at different angles, however, different loads did not exhibit specific variability to any significant extent. The explanation of the former result is the object of this discussion. Strength, when measured by Shaw (101) was found to be specific when measures were taken with an angle separation of 90 degrees, but more general than specific when measured with a smaller degree separation ( $45^{\circ}$ ). This idea has been extended in the strength training direction, by Gardner (37) who found that strength increases were specific to the training angle. This could possibly be the key to the results discovered in the present study: the fact that humans walk and stand (with knee angle close to  $160^{\circ}$ ) far more than they run or





or climb stairs (requiring knee angles around  $130^{\circ}$  or less). It may simply be that the quadriceps are better trained at the more extended angle. Even more than this, the 'training' or day-to-day activity that the quadriceps muscle goes through at these different angles of knee extension may not be highly related, angle to angle. Another factor is that when the muscle is contracted at different angles a differential blood occlusion factor might take place. Different muscles have been known to vary in the extent of contraction needed to occlude the blood (6, 97, 104). That is, it is possible that at 160 degrees extension, for example, a load of 50 percent occludes circulation, and at 130 degrees extension, a load of 25 percent occludes circulation, meaning that a different variable would be present to increase specific variability of the measures. Wilkie (118) claims that muscle produces tension as a function of its own length. Examination of Table IV will show that there is, indeed, a great difference in strength at these angles. This advantage to produce greater tension in a single contraction may, in fact, place far greater strain on the muscle and hence be a disadvantage to holding tension, thereby increasing variability between measures.

The following remarks by Rich (91:497) should be observed when interpreting the present study:



Caution must be exercised to avoid over-generalizing from the results of the present study. It would seem obvious that no research should be fully accepted until the results have been confirmed by others. Equally important, the observations need to be extended to other muscle groups ...



## CHAPTER V

### SUMMARY AND CONCLUSIONS

It was the principal purpose of this study to examine the performance of four similar measures of holding endurance, to subsequently determine the relationships among these measures and to finally interpret the degree to which the abilities to perform these tasks were specific to the particular tasks in question.

Further observations were recorded regarding age, height, weight, leg lengths, and maximum isometric strength of the right quadriceps.

The subjects were forty-two male students chosen randomly from a select group of Physical Education service program classes at the University of Alberta, Edmonton.

Each subject attended three testing sessions of slightly less than one hour per session. In the first session age, height, weight and leg lengths of hip to knee, knee to ankle and total leg were recorded. Maximum isometric strength was also obtained at this time for both testing positions - with the knee extended to 130 degrees and to 160 degrees. Loads of 30 percent and 45 percent were then calculated for the endurance measures at each angle. Two of the four maximum holding endurance time measures were obtained at





each of the last two sessions, with the different tests taken in random order.

The following conclusions are made:

1. There was a substantial component of holding endurance found but in combination with a second angle component it was observed that the measures of endurance were specific to the angle of knee extension at which the measure was taken.
2. Isometric strength measured at a knee extension angle of 160 degrees was highly related to isometric strength measured at 130 degrees.
3. Of six isometric strength correlations with holding endurance, all were negative but only one was significantly different from zero.
4. A moderate correlation was found to exist between knee-ankle length and holding endurance but subsequent 'partialling out' did not substantially change the pattern of holding endurance intercorrelations.
5. Holding endurance was not found to be specific to the load used in testing.

Recommendations.

1. Further research in this area is needed with respect to different muscles.
2. To extend the findings of the present study, further study should be made of the function of angle separation



on both strength and endurance holding measures.

3. Further research is needed to uncover the relative importance of motivation, pain tolerance, circulation occlusion and leg lengths to the performance of muscular endurance tasks.



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## APPENDICES



## STATISTICAL TREATMENT

Correlation Coefficients and Test Reliabilities. The correlation coefficients and test reliabilities were obtained along with means, variances, standard deviations, sums of squares and cross-products through an I.B.M. - 7040 Electronic Computer programmed to compute correlation and reliability coefficients using the Pearson product-moment method of calculation.

Significance of a Correlation Coefficient. The significance of the correlation coefficient was ascertained through examination of Ferguson's Critical Values of the Correlation Coefficient (33:315), with N-2 degrees of freedom, where N = the number of subjects.

Partial Correlations. Partial Correlations were obtained using the formula

$$r_{12.3} = \frac{r_{12} - r_{13}r_{23}}{\sqrt{1 - (r_{13})^2} \sqrt{1 - (r_{23})^2}} \quad \begin{array}{l} (33:291) \\ (76:167) \end{array}$$

Where  $r_{12.3}$  is interpreted as the correlation coefficient between variables 1 and 2 with variable 3 held constant or partialled out of both 1 and 2.

Component Analysis. Component Analysis was accomplished through an I.B.M. - 7040 Computer with program provided by Hunka (52). Through this analysis of all MHET measurements, eigenvalues and principal components were obtained (60).



DATA SHEET

# \_\_\_\_\_

J. P. Stothart

NAME \_\_\_\_\_ ADDRESS \_\_\_\_\_ PHONE \_\_\_\_\_  
AGE \_\_\_\_\_ yrs. \_\_\_\_\_ mos. TOTAL LEG LENGTH \_\_\_\_\_ ins.  
HEIGHT \_\_\_\_\_ ins. HIP - KNEE LENGTH \_\_\_\_\_ ins.  
WEIGHT \_\_\_\_\_ lbs. KNEE - ANKLE LENGTH \_\_\_\_\_ ins.

| MAX. ISOMET. STRENGTH | TRAIL 1 | TRIAL 2 | AVERAGE | 30%   | 45%   |
|-----------------------|---------|---------|---------|-------|-------|
| 160°                  | _____   | _____   | _____   | _____ | _____ |
| DATE _____ 130°       | _____   | _____   | _____   | _____ | _____ |
| 115°                  | _____   | _____   | _____   | _____ | _____ |

HOLDING ENDURANCE TIMES

| DATE | ANGLE | PERCENTAGE | ORDER | TRIAL 1 | TRIAL 2 | AVERAGE |
|------|-------|------------|-------|---------|---------|---------|
|      | 160°  | 30         |       |         |         |         |
|      | 160°  | 45         |       |         |         |         |
|      | 130°  | 30         |       |         |         |         |
|      | 130°  | 45         |       |         |         |         |

COMMENTS :





APPENDIX C  
ANGLE INDICATOR UNIT CIRCUIT



APPENDIX D

RAW DATA





# RAW SCORES FOR VITAL STATISTICS

| Sub.<br>No. | Age<br>(Mos.) | Height<br>(Ins.) | Weight<br>(lbs.) | Hip-Knee<br>(ins.) | Knee-Ankle<br>(ins.) | Total Leg<br>(ins.) |
|-------------|---------------|------------------|------------------|--------------------|----------------------|---------------------|
| 1.          | 338           | 70.5             | 148              | 16.0               | 16.4                 | 32.4                |
| 2.          | 237           | 68.0             | 144              | 16.4               | 16.1                 | 32.5                |
| 3.          | 252           | 68.5             | 140              | 16.8               | 17.0                 | 33.8                |
| 4.          | 255           | 71.0             | 191              | 16.8               | 17.8                 | 34.5                |
| 5.          | 243           | 71.0             | 174              | 17.0               | 17.5                 | 34.5                |
| 6.          | 241           | 66.0             | 134              | 15.6               | 15.5                 | 31.1                |
| 7.          | 229           | 73.0             | 145              | 16.0               | 17.8                 | 33.8                |
| 8.          | 229           | 72.0             | 179              | 17.4               | 17.8                 | 35.1                |
| 9.          | 229           | 66.5             | 160              | 15.0               | 16.8                 | 31.8                |
| 10.         | 223           | 68.0             | 118              | 16.5               | 16.8                 | 33.3                |
| 11.         | 226           | 74.0             | 163              | 17.5               | 18.8                 | 36.3                |
| 12.         | 224           | 69.5             | 159              | 16.1               | 17.3                 | 33.4                |
| 13.         | 226           | 66.0             | 140              | 15.3               | 15.0                 | 30.3                |
| 14.         | 228           | 70.5             | 184              | 16.0               | 17.0                 | 33.0                |
| 15.         | 279           | 70.0             | 170              | 16.3               | 16.8                 | 33.0                |
| 16.         | 241           | 68.5             | 145              | 15.5               | 16.0                 | 31.5                |
| 17.         | 230           | 68.0             | 159              | 16.0               | 16.0                 | 32.0                |
| 18.         | 231           | 65.5             | 142              | 14.8               | 16.0                 | 30.8                |
| 19.         | 238           | 73.0             | 150              | 18.0               | 18.5                 | 36.5                |
| 20.         | 235           | 72.8             | 175              | 17.5               | 17.9                 | 35.4                |
| 21.         | 228           | 67.5             | 128              | 15.5               | 15.9                 | 31.4                |
| 22.         | 224           | 69.0             | 152              | 16.4               | 16.3                 | 32.7                |
| 23.         | 332           | 66.0             | 125              | 15.3               | 15.4                 | 30.7                |
| 24.         | 243           | 72.5             | 170              | 16.8               | 18.0                 | 34.8                |
| 25.         | 223           | 71.0             | 174              | 16.3               | 16.8                 | 33.1                |
| 26.         | 229           | 70.5             | 167              | 17.0               | 16.8                 | 33.8                |
| 27.         | 293           | 71.0             | 171              | 16.3               | 17.0                 | 33.3                |
| 28.         | 217           | 73.5             | 177              | 17.0               | 17.3                 | 34.3                |
| 29.         | 224           | 70.3             | 159              | 16.9               | 17.0                 | 33.9                |
| 30.         | 224           | 71.0             | 169              | 16.5               | 16.9                 | 33.4                |
| 31.         | 222           | 70.3             | 184              | 17.0               | 16.4                 | 33.4                |
| 32.         | 228           | 68.3             | 171              | 17.0               | 16.0                 | 33.0                |
| 33.         | 225           | 74.5             | 157              | 17.8               | 18.8                 | 36.6                |
| 34.         | 245           | 69.8             | 161              | 16.8               | 16.5                 | 33.3                |
| 35.         | 220           | 68.5             | 172              | 16.0               | 16.5                 | 32.5                |
| 36.         | 217           | 69.0             | 133              | 16.5               | 17.0                 | 33.5                |
| 37.         | 227           | 67.5             | 138              | 15.8               | 16.4                 | 32.2                |
| 38.         | 224           | 69.5             | 177              | 17.0               | 17.3                 | 34.3                |
| 39.         | 260           | 73.5             | 200              | 15.5               | 17.8                 | 33.3                |
| 40.         | 230           | 73.0             | 163              | 17.9               | 18.3                 | 36.2                |
| 41.         | 237           | 68.0             | 160              | 15.5               | 16.5                 | 32.0                |
| 42.         | 228           | 69.0             | 165              | 17.3               | 16.8                 | 34.1                |



# RAW SCORES FOR MIMS

| Sub.<br>No. | MIMS 160 <sup>o</sup> |         |         | MIMS 130 <sup>o</sup> |         |         |
|-------------|-----------------------|---------|---------|-----------------------|---------|---------|
|             | Trial 1               | Trial 2 | Average | Trial 1               | Trial 2 | Average |
| 1.          | 63                    | 73      | 68.0    | 197                   | 193     | 195.0   |
| 2.          | 93                    | 100     | 96.5    | 248                   | 244     | 246.0   |
| 3.          | 77                    | 90      | 83.5    | 193                   | 208     | 200.5   |
| 4.          | 95                    | 112     | 103.5   | 252                   | 265     | 258.5   |
| 5.          | 97                    | 92      | 94.5    | 252                   | 244     | 248.0   |
| 6.          | 75                    | 75      | 75.0    | 216                   | 212     | 214.0   |
| 7.          | 73                    | 70      | 71.5    | 212                   | 216     | 214.0   |
| 8.          | 113                   | 107     | 110.0   | 280                   | 260     | 270.0   |
| 9.          | 112                   | 114     | 113.0   | 306                   | 300     | 303.0   |
| 10.         | 69                    | 75      | 72.5    | 151                   | 154     | 152.5   |
| 11.         | 92                    | 100     | 96.0    | 233                   | 220     | 227.0   |
| 12.         | 77                    | 90      | 83.5    | 240                   | 227     | 233.5   |
| 13.         | 83                    | 73      | 78.0    | 232                   | 208     | 220.0   |
| 14.         | 95                    | 105     | 100.0   | 235                   | 256     | 245.5   |
| 15.         | 97                    | 110     | 103.5   | 193                   | 212     | 202.5   |
| 16.         | 73                    | 80      | 76.5    | 167                   | 177     | 172.5   |
| 17.         | 113                   | 112     | 112.5   | 256                   | 244     | 250.0   |
| 18.         | 72                    | 70      | 71.0    | 240                   | 220     | 230.0   |
| 19.         | 105                   | 105     | 105.0   | 233                   | 237     | 235.0   |
| 20.         | 95                    | 87      | 91.0    | 223                   | 204     | 213.5   |
| 21.         | 100                   | 102     | 101.0   | 227                   | 240     | 233.5   |
| 22.         | 104                   | 104     | 104.0   | 240                   | 265     | 252.5   |
| 23.         | 55                    | 63      | 59.0    | 193                   | 200     | 296.5   |
| 24.         | 118                   | 118     | 118.0   | 280                   | 256     | 268.0   |
| 25.         | 133                   | 133     | 133.0   | 306                   | 324     | 315.0   |
| 26.         | 115                   | 125     | 120.0   | 275                   | 270     | 272.5   |
| 27.         | 92                    | 83      | 87.5    | 256                   | 244     | 250.0   |
| 28.         | 100                   | 95      | 102.5   | 208                   | 240     | 224.0   |
| 29.         | 63                    | 63      | 63.0    | 193                   | 193     | 193.0   |
| 30.         | 112                   | 112     | 112.0   | 270                   | 265     | 267.5   |
| 31.         | 95                    | 97      | 96.0    | 212                   | 234     | 223.5   |
| 32.         | 133                   | 135     | 134.0   | 315                   | 332     | 323.5   |
| 33.         | 112                   | 113     | 112.5   | 235                   | 244     | 239.5   |
| 34.         | 82                    | 85      | 83.5    | 220                   | 220     | 220.0   |
| 35.         | 120                   | 112     | 116.0   | 244                   | 248     | 246.0   |
| 36.         | 59                    | 68      | 63.5    | 212                   | 190     | 201.0   |
| 37.         | 98                    | 93      | 95.5    | 244                   | 220     | 232.0   |
| 38.         | 97                    | 85      | 91.0    | 248                   | 290     | 269.0   |
| 39.         | 100                   | 116     | 108.0   | 224                   | 260     | 242.0   |
| 40.         | 78                    | 97      | 87.5    | 197                   | 216     | 206.5   |
| 41.         | 97                    | 95      | 96.0    | 220                   | 230     | 225.0   |
| 42.         | 115                   | 130     | 122.5   | 324                   | 324     | 324.0   |



# RAW SCORES FOR MHET AT 160°

| Sub.<br>No. | MHET with 30% Load |         |         | MHET with 45% Load |         |         |
|-------------|--------------------|---------|---------|--------------------|---------|---------|
|             | Trial 1            | Trial 2 | Average | Trial 1            | Trial 2 | Average |
| 1.          | 328                | 196     | 262.0   | 95                 | 65      | 80.0    |
| 2.          | 155                | 173     | 164.0   | 117                | 103     | 110.0   |
| 3.          | 231                | 173     | 202.0   | 142                | 117     | 129.5   |
| 4.          | 250                | 179     | 214.5   | 193                | 147     | 170.0   |
| 5.          | 153                | 136     | 144.5   | 117                | 102     | 109.5   |
| 6.          | 235                | 173     | 204.0   | 131                | 88      | 109.5   |
| 7.          | 367                | 273     | 320.0   | 218                | 170     | 194.0   |
| 8.          | 285                | 183     | 234.0   | 176                | 137     | 156.5   |
| 9.          | 168                | 233     | 200.5   | 129                | 88      | 108.5   |
| 10.         | 223                | 222     | 222.5   | 132                | 101     | 116.5   |
| 11.         | 303                | 243     | 273.0   | 131                | 106     | 118.5   |
| 12.         | 302                | 199     | 249.5   | 222                | 126     | 174.0   |
| 13.         | 214                | 143     | 178.5   | 128                | 99      | 113.5   |
| 14.         | 282                | 148     | 215.0   | 185                | 90      | 137.5   |
| 15.         | 115                | 123     | 119.0   | 73                 | 77      | 75.0    |
| 16.         | 257                | 209     | 233.0   | 185                | 157     | 171.0   |
| 17.         | 181                | 150     | 165.5   | 125                | 87      | 106.0   |
| 18.         | 171                | 113     | 142.0   | 99                 | 86      | 92.5    |
| 19.         | 320                | 136     | 228.0   | 136                | 106     | 121.0   |
| 20.         | 294                | 156     | 225.0   | 197                | 129     | 163.0   |
| 21.         | 72                 | 85      | 78.5    | 45                 | 44      | 44.5    |
| 22.         | 184                | 171     | 177.5   | 128                | 87      | 107.5   |
| 23.         | 189                | 156     | 172.5   | 132                | 130     | 131.0   |
| 24.         | 248                | 214     | 231.0   | 138                | 135     | 136.5   |
| 25.         | 169                | 127     | 148.0   | 93                 | 95      | 94.0    |
| 26.         | 149                | 136     | 142.5   | 138                | 86      | 112.0   |
| 27.         | 254                | 231     | 242.5   | 132                | 90      | 111.0   |
| 28.         | 229                | 211     | 220.0   | 113                | 103     | 108.0   |
| 29.         | 265                | 217     | 246.0   | 172                | 149     | 160.5   |
| 30.         | 250                | 179     | 214.5   | 149                | 118     | 133.5   |
| 31.         | 257                | 342     | 299.5   | 152                | 110     | 131.0   |
| 32.         | 200                | 155     | 177.5   | 157                | 110     | 133.5   |
| 33.         | 250                | 154     | 202.0   | 181                | 106     | 143.5   |
| 34.         | 280                | 230     | 255.0   | 152                | 133     | 142.5   |
| 35.         | 143                | 96      | 119.5   | 81                 | 79      | 80.0    |
| 36.         | 385                | 279     | 332.0   | 186                | 144     | 165.0   |
| 37.         | 121                | 121     | 121.0   | 73                 | 75      | 74.0    |
| 38.         | 296                | 254     | 275.0   | 163                | 176     | 169.5   |
| 39.         | 366                | 321     | 343.5   | 241                | 212     | 226.5   |
| 40.         | 336                | 271     | 303.5   | 249                | 142     | 195.5   |
| 41.         | 190                | 145     | 167.5   | 126                | 99      | 112.5   |
| 42.         | 135                | 130     | 132.5   | 117                | 88      | 102.5   |







# RAW SCORES FOR MHET AT 130°

| Sub.<br>No. | MHET with 30% Load |         |         | MHET with 45% Load |         |         |
|-------------|--------------------|---------|---------|--------------------|---------|---------|
|             | Trial 1            | Trial 2 | Average | Trial 1            | Trial 2 | Average |
| 1.          | 94                 | 58      | 76.0    | 82                 | 47      | 64.5    |
| 2.          | 102                | 75      | 88.5    | 63                 | 51      | 57.0    |
| 3.          | 150                | 108     | 129.0   | 70                 | 59      | 64.5    |
| 4.          | 117                | 92      | 104.5   | 96                 | 82      | 89.0    |
| 5.          | 89                 | 87      | 88.0    | 60                 | 64      | 62.0    |
| 6.          | 92                 | 71      | 81.5    | 70                 | 58      | 64.0    |
| 7.          | 134                | 103     | 118.5   | 117                | 63      | 90.0    |
| 8.          | 120                | 85      | 102.5   | 64                 | 65      | 64.5    |
| 9.          | 93                 | 88      | 90.5    | 59                 | 62      | 60.5    |
| 10.         | 192                | 136     | 164.0   | 95                 | 82      | 88.5    |
| 11.         | 130                | 119     | 124.5   | 73                 | 57      | 65.0    |
| 12.         | 132                | 120     | 126.0   | 88                 | 73      | 80.5    |
| 13.         | 99                 | 72      | 85.5    | 58                 | 49      | 53.5    |
| 14.         | 160                | 119     | 139.5   | 94                 | 82      | 88.0    |
| 15.         | 81                 | 75      | 78.0    | 53                 | 55      | 54.0    |
| 16.         | 190                | 129     | 159.5   | 65                 | 65      | 65.0    |
| 17.         | 95                 | 76      | 85.5    | 56                 | 47      | 51.5    |
| 18.         | 94                 | 72      | 83.0    | 55                 | 50      | 52.5    |
| 19.         | 141                | 90      | 115.5   | 78                 | 62      | 70.0    |
| 20.         | 118                | 69      | 93.5    | 63                 | 72      | 67.5    |
| 21.         | 42                 | 45      | 43.5    | 21                 | 29      | 25.0    |
| 22.         | 88                 | 86      | 87.0    | 59                 | 65      | 62.0    |
| 23.         | 84                 | 73      | 78.5    | 56                 | 52      | 54.0    |
| 24.         | 158                | 111     | 134.5   | 77                 | 94      | 85.5    |
| 25.         | 78                 | 63      | 70.5    | 46                 | 40      | 43.0    |
| 26.         | 93                 | 86      | 89.5    | 87                 | 75      | 81.0    |
| 27.         | 86                 | 76      | 81.0    | 73                 | 61      | 67.0    |
| 28.         | 110                | 72      | 91.0    | 47                 | 40      | 43.5    |
| 29.         | 159                | 108     | 133.5   | 92                 | 88      | 90.0    |
| 30.         | 95                 | 95      | 95.0    | 58                 | 50      | 54.0    |
| 31.         | 98                 | 77      | 87.5    | 57                 | 55      | 56.0    |
| 32.         | 97                 | 93      | 95.0    | 60                 | 63      | 61.5    |
| 33.         | 123                | 101     | 112.0   | 91                 | 87      | 89.0    |
| 34.         | 97                 | 93      | 95.0    | 78                 | 66      | 72.0    |
| 35.         | 106                | 88      | 97.0    | 68                 | 54      | 61.0    |
| 36.         | 91                 | 75      | 83.0    | 80                 | 71      | 75.5    |
| 37.         | 99                 | 79      | 89.0    | 71                 | 60      | 65.5    |
| 38.         | 114                | 75      | 94.5    | 72                 | 60      | 66.0    |
| 39.         | 219                | 179     | 199.0   | 136                | 111     | 123.5   |
| 40.         | 120                | 86      | 103.0   | 59                 | 65      | 62.0    |
| 41.         | 103                | 95      | 99.0    | 73                 | 71      | 72.0    |
| 42.         | 81                 | 87      | 84.0    | 77                 | 65      | 71.0    |





